A Three-Phase, Five-Level Multilevel Inverter with Output Voltage Boost

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Abstract

A three-phase full-bridge circuit with an added bidirectional switch has been used to generate 5-level output voltage by splitting a dc voltage source with two capacitors. The issue of voltage imbalance between the splitting capacitors and the limitation of the output voltage to the value of the input voltage source are both connected to this configuration. A unit topology for a five-level, three-phase MLI is proposed in this paper. It consists of an H-bridge circuit, a capacitor, a charge-discharge unit, and a dc source in each phase-leg. The interface between the H– bridge and the dc source is the charge discharge unit with the capacitor. The proposed unit cell can produce a phase leg output voltage waveform with five levels and a peak voltage twice as high as the input voltage; resulting in the creation of nine-level waveforms of the output line voltage. The proposed circuit's ability to boost output voltage is its most notable feature. The outcomes of the prototype and simulation experiments are presented

1. Introduction

A converter that converts DC to AC power is an inverter. Because circuits for inverters can be very complicated, the goal of this approach is to show some of the inner workings of inverters without getting bogged down in the finer points. In power electronics, the term "inverter" refers to a power conversion circuit that converts DC voltage or current into AC voltage or current.

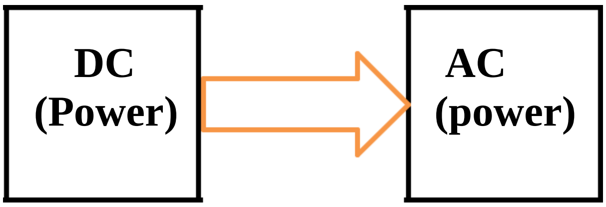

Fig.1 Inverter operation

Even though the source of the input to an inverter circuit is DC, it is not uncommon for this DC to come from an AC source like a utility AC supply. As a result, "the primary source of input power may, for instance, be a utility AC voltage supply that is converted to DC by an AC to DC converter and then inverted back to AC by an inverter." The utility supply's input ac may have a frequency or magnitude that is different from the final output in this case. Examples of typical applications include traction, HVDC, and uninterruptible power supplies (UPS).

Multilevel inverters (MLIs) have emerged and developed, and their applications in power electronics have shown significant promise [1]. The use of MLIs in the integration of renewable energy is rapidly expanding due to their ability to reduce output harmonics and transformer-free boosted output voltage [2, 3]. Traditional established MLI topologies like diode clamped [4–7], flying capacitor (FC) [8], and cascaded H bridge (CHB) [9–12] have been extensively studied for electrical energy conversion systems [13, 14]. Configuration calls for multiple isolated voltage sources, and the number of power switches increases significantly when there are more output voltage levels [10–12]. In addition, the issue of voltage balancing in dc-link series capacitor banks exists in both capacitor-clamped and neutral-point-clamped inverters [15–17]; requiring advanced and complex control and modulation methods.

Due to these drawbacks, research efforts have focused on creating new MLI topologies with improved performance. Many of these are derived from full-bridge inverters and traditional MLI configurations [18, 19]. The 3-phase bridge inverter was modified with the help of pre-clamping bidirectional switches in [20]. resulting in the synthesis of three-phase output voltages at multiple levels. An advanced space vector modulation scheme and a generalized power circuit configuration for optimal use of the bidirectional switches were proposed in this section. In the work that was presented in [21], this inverter configuration was hybridized with a half-bridge inverter per phase that was independently powered. There is a problem with the high demand for isolated voltage sources in both [21] and due to its asymmetrical configuration, the worst case scenario is in. In addition, there is unquestionably no modularity in the power circuit layout of either of the inverter topologies. The MLI configurations suggested in [22] and [23] also contain these flaws in topological features. Due to its modularity and capability of voltage boosting, CHB is the most popular MLI topology for renewable energy conversion systems.

Modifying the H-bridge through module configurations that are more compact and have fewer switches is the recent research trend. The newly developed module topologies are more efficient while simultaneously producing more voltage levels [18, 19]. Due to its continued popularity in generating multiple voltage levels, the CHB concept of switched DC sources is largely preserved [24–26]. The main idea behind module topology is usually to add more circuits so that the voltage level across the DC link of the H-bridge is higher. Most of the time, this extra circuitry has a separate voltage source and/or banks of switched capacitors. The separate control of voltage level generation and output voltage steering will be made easier by this improvement. Some recent inverter topologies and control strategies that make use of the aforementioned principle are presented in works [27–34]. All in all, the goal is to get a very high level of pre-stepped output voltage waveform that is impressed on an H-bridge for voltage inversion further down the line.

2. Literature Review

The topology of multilevel converters is given a chronological overview in this paper, and the various terminology and characteristics of these converters are discussed. Three-level neutral-point-clamped (NPC) and neutral-point-piloted (NPP) inverters, four-level flying-capacitor

(FLC) inverters, and a family of modular multilevel cascade converters are all examples of the multilevel converters [1].

MLIs are ideal for both domestic and industrial applications due to their low harmonic content. Traditional MLI topologies' performance issues, such as low power quality, low efficiency, and uneconomical structure, prevent them from being used in conjunction with the current advancements in renewable energy systems (RES). New hybrid MLI topologies have been developed by researchers in response to these limitations in the performance issues of traditional MLI topologies [2].

For the proposed multilevel inverter, a modulation method is described. The level module units that make up this multilevel inverter structure are used to raise the level of the output voltage. This structure makes it possible to reduce the size and cost of the system because a level module unit only requires a bidirectional switch and a DC voltage source. Analysis and simulation have shown that the proposed topology is effective [4].

A voltage source inverter with three phases and multiple levels is shown in this paper to raise the output voltage. The proposed inverter is set up by adding a capacitor bank to the output terminals of a modified H-bridge in each phase. It is possible to generate three-level phase-leg output voltage waveforms with peak values that are twice as large as those of a single-input voltage in this configuration; resulting in the creation of 5-level waveforms of the output line voltage. The inverter control operation uses a low frequency switching scheme based on Fourier series analysis [5].

The five-level inverter neutral-point-clamped NPC topology is the subject of this paper's investigation of various modulation techniques. The voltage inverter three-phase, five-level NPC topology was first described. After that, we model the inverter and control it with different strategies. Then, we compared the results of the different strategies [6] and used networks to reduce the ground-fault current. For the FASD, a lot of HBs are needed because the ground fault produces a lot of voltage and current. An improved distributed commutations modulation method and the flexible arc-suppression method are proposed to modulate the HBs [12].

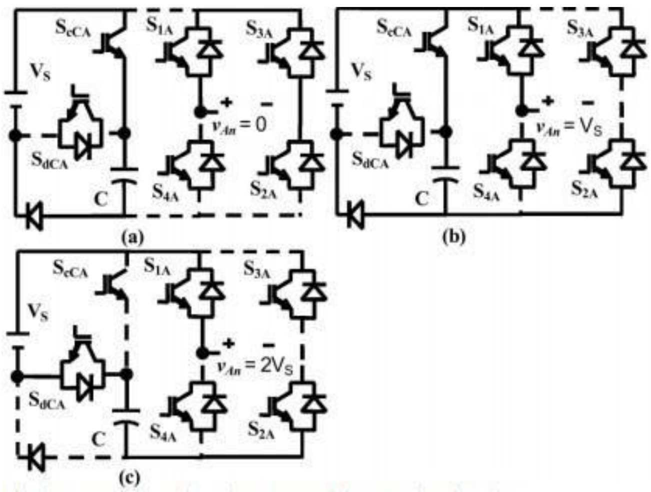

Fig.2 Inverter Modules

The paper deals with introduction proposed system introduction and circuit configuration and its operation.

- The second chapter deals with pulse with modulation, types and comparison.
- The third chapter deals with types of multilevel inverter, operation and features.
- The fourth chapter deals with MATLAB/SIMULINK introduction i.e. A THREE-PHASE, FIVE-LEVEL INVERTER WITH OUTPUT VOLTAGE BOOST.
- The fifth chapter deals with simulation and experimental results.
- The sixth chapter deals with simulation results and waveforms.
- The seventh chapter deals with conclusion and references

3. Proposed System

The configuration of the module in [27] is a cascade of half-bridge circuits each with its own isolated dc source. Six half-bridge cells in a cascade were shown there; resulting in a single-phase output voltage waveform with 13 levels. In [28–31], similar power circuits were presented. The isolated dc source demand for each output voltage step is a major drawback of these configurations. This issue was resolved by using switched capacitor banks in the module configuration in the studies [32] and [33]. When compared to the power circuit in [32], a smaller circuit component count was achieved in both symmetrical and asymmetrical configurations in [33]. The capacitor voltage values must be controlled in both configurations; with an additional control circuit. Sung-Jun Park and others proposed using a bidirectional switch to connect the H-bridge to a cascade of two dc sources [34]. Each cycle of this single-phase inverter configuration generates a 5-level output voltage waveform; as a result, it performs better in terms of total harmonic distortion (THD) than the three-level H-bridge. In [34] and [35], it is evident that the demand for isolated dc sources is inherently required in these topologies. Work carried out in [35] extended this topology to accommodate more dc sources for higher output voltage levels. In [36], two capacitor banks that split a single dc voltage source took the place of the two isolated dc sources in [34]. The arrangement is depicted in Figure. 1(a). The count of switches in the power circuit and the operating principle are unchanged. This capacitor-split, 5-level inverter configuration's single-phase cascaded structure was shown in [37]; where the synthesis of a 9-level output voltage waveform was demonstrated in a configuration.

The cascaded configuration in [37] was extended to a three-phase system thanks to the work done in [38]. The inverter topology suggested in [36] has a limit on the magnitude of the output voltage; governed by the one and only DC input source. Additionally, there is a voltage disparity between the banks of splitting capacitors; and because of this, an additional control circuit, as well as its derivatives in [37] and [38], are required for this inverter configuration. This paper proposes a topology for boosting the output voltage of a three-phase, five-level multilevel level inverter in light of these flaws. The inherent output voltage limitation and its derivatives can be overcome with the configuration of the proposed inverter. As a result, the proposed three-phase MLI's per phase configuration with a single dc input can generate a 5-level output voltage waveform; whose amplitude is double the value of the input voltage.

Additionally, just one capacitor bank is utilized; As a result, voltage imbalance is not a problem. In terms of the output voltage waveform and its spectrum, the operational configuration of the proposed three-phase inverter structure is comparable to that shown in [38]. However, the increased output voltage value and the absence of splitting capacitor banks appear to be the primary distinction and, consequently, the improvement; with the imbalance issue that comes with them. Additionally, the proposed inverter configuration has a significantly lower component count than the conventional CHB inverter; and matches the same output voltage level as the configuration in [38].

As a result, precisely In-phase disposition modulation is used to generate the six gating signals [39] and [40] in each module of a phase-leg, level shifted PWM scheme. Figure depicts the modulation scheme utilized in a phase-leg module. 4. From this picture, 4, when the modulating sine wave signal R is compared to the zero value, the switching signal S1A is produced whenever R is greater than zero. Additionally, the remaining switching signals are determined by applying the fundamental logic AND, OR, and NOT gat by comparing the disposed carrier signals T1 through T4 with Re

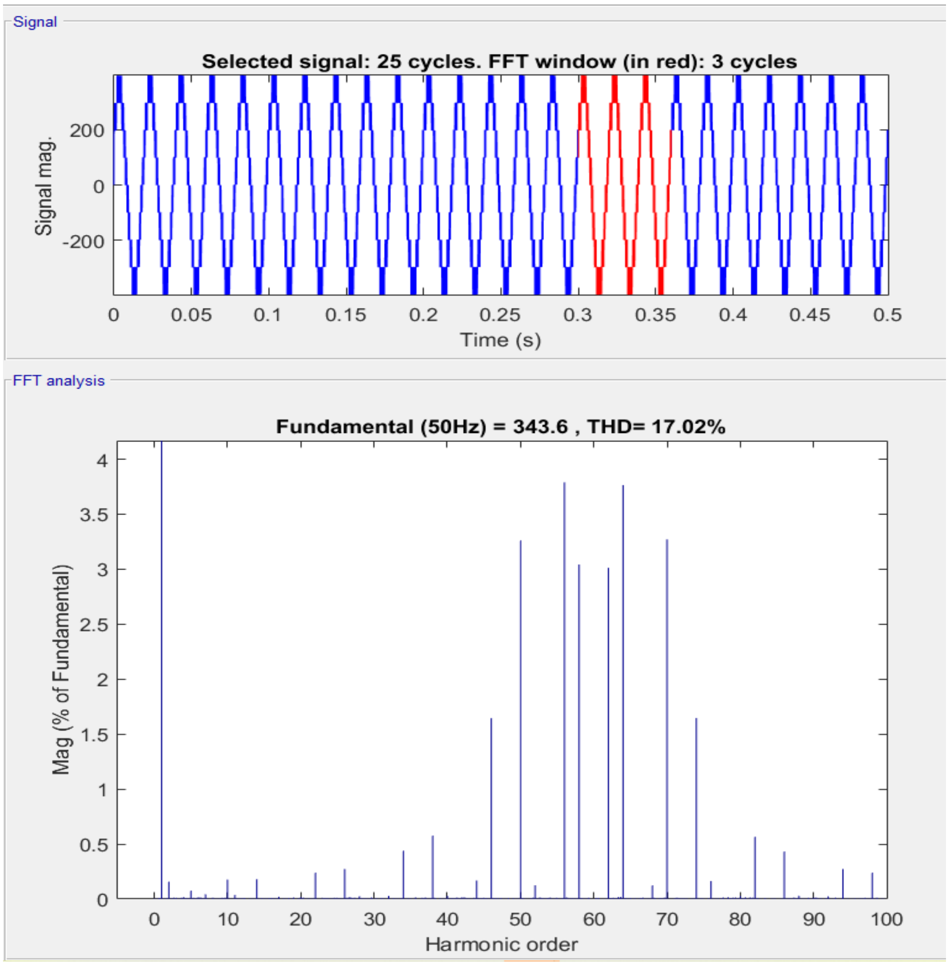

Fig.4 PExperimental Results

V_{An}	S_{cCA}	S_{dCA}	S_{1A}	S_{2A}	S_{3A}	S_{4A}
0	1	0	1	0	1	0
V_S	1	0	1	1	0	0
V_S	0	1	1	1	0	0
0	1	0	0	1	0	1
$-V_S$	1	0	0	0	1	1
$-2V_S$	1	0	0	0	1	1

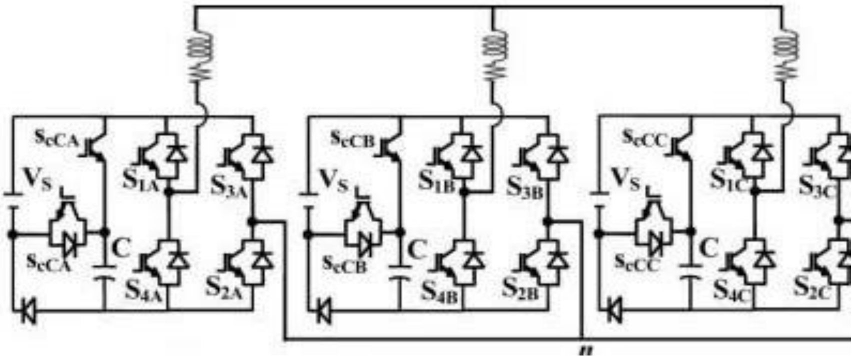

Fig.5 Proposed Structure

4. Conclusion

An inverter topology for boosting the output voltage of a three-phase, five-level multilevel level inverter is described in this paper. In-depth explanations of the switching principles, modulation scheme, and functions have been provided. For the synthesis of any output voltage level, three of the six power switches in each phase-leg cell are simultaneously activated. One of these switches is switched at the fundamental frequency, while the other two are pulse-width modulated. This ensures that the power switches undergo as few switching transitions as possible. The proposed MLI allows for a maximum of five level output voltage waveforms to be generated by each phase-leg module; which has twice the amplitude of the single input voltage source. The proposed inverter configuration's frequency spectra of synthesized output line voltage waveforms with a modulation index of 0.9 have been demonstrated. Simulations and laboratory tests on the proposed inverter for an R-L load have shown that the topology of the inverter works as intended; The results have been presented appropriately

References

1. H. Akagi, “Multilevel Converters: Fundamental Circuits and Systems,” Proc. IEEE, vol. PP, no. 99, 2017.
2. P. Kala and S. Arora, “A Comprehensive Study of Classical and Hybrid Multilevel Inverter Topologies for Renewable Energy Applications,” Renew. Sustain. Energy Rev., vol. 76, pp. 905–931, 2017.
3. C. Cerati, F. Concetta, and P. Sian, “A Multilevel Inverter for Photovoltaic Systems with Fuzzy Logic Control,” IEEE Trans. Ind. Electron., vol. 57, no. 12, pp. 4115–4125, 2010.
4. R. H. Baker, “High-voltage converter circuit”, US Patent 04-203- 151, May 1980.
5. A. Nabe, I. Takahashi and H. Akagi, “A new neutral-point clamped PWM inverter”, in Proceeding of the industry application society conference, 1980. p. 761–6.

6. A. Nabe, I. Takahashi, and H. Akagi, "A New Neutral-point Clamped PWM inverter," IEEE Trans. Ind. Applications, vol. IA-17, pp. 518- 523, Sept./Oct. 1981.
7. J. Rodriguez, S. Barnet, P. K. Steamer and I. E. Lezama, "A survey on neutral-point-clamped inverters," IEEE Trans. Ind. Electron., vol. 57, no. 7, pp. 2219–2230, Jul. 2010.
8. T. A. Maynard and H. Foch, "Multi-level conversion: high-voltage chopper and voltage source inverters," Conference Record of the 1992 IEEE Power Electronics Specialists Conference (PESC), pp. 397–403, Toledo, Spain, 29 June–3 July 1992.
9. R. H. Baker, "Electric power converter", US Patent 03-867-643; February 1975.
10. M. Malinowski, K. Gopak Umar, J. Rodriguez and M. A. Perez, "A survey on cascaded multilevel inverters," IEEE Trans. Ind. Electron., vol. 57, no. 7, pp. 2197–2206, Jul. 2010.
11. H. Setalvad, J. Liao, M. Ferdowsi, and K. A. Corzine, "Capacitor voltage regulation in single-DC-source cascaded H-bridge multilevel converters using phase-shift modulation," IEEE Trans. Ind. Electron., vol. 60, no. 9, pp. 3619–3626, Sep. 2013.
12. B. P. McGrath, D. G. Holmes, and W. Y. Kong, "A decentralized controller architecture for a cascaded H-bridge multilevel converter," IEEE Translink. Electron., vol. 61, no. 3, pp. 1169– 1178, Mar. 2014